necessity for some greater control over fast passenger trains was thus rendered obvious. Through the want of a larger amount of brake power much time was lost on a journey, when the stoppages were frequent, the drivers being compelled to slacken speed at long distances from the stopping-places. It seemed, indeed, scarcely to admit of question that a system which was deemed necessary in special cases might be advantageously applicable in all cases; that to render the control of a train complete, brakes should be applied to all, or nearly all, the wheels; and that, at least, the driver, if not the guards, should possess the power of promptly bringing the whole into action. The truth of the principle was now very generally admitted by the leading companies, some of whom had already adopted continuous brakes, while others were preparing to do so. Rather startling disparities were disclosed during the experiments. Some of the disparities were attributable to the contrivances being of comparatively recent origin, but others were clearly owing to the principle upon which the action of the brake was founded. As between the air-pressure and the vacuum brakes there was a loss of 6¼ seconds, which in a train running sixty miles an hour was equivalent to 180 yards additional space traversed in the stop. Three of the experiments involved the application of all available power for stopping. Sand was used, and was found to add sensibly to the stopping power. On an average it made an addition of 1·30 per cent. to the retarding force otherwise brought into play. The trials proved in a very striking manner the great advantage of continuous brakes, for even in their least effective form they afforded more than double the stopping power of the usual hand brakes, whilst in their most effective form the power was quadrupled. He was of opinion that no system could be considered satisfactory which did not produce a retarding power of at least 8 to 10 per cent. of the entire weight of the train, in other words, a power by which fast trains could be stopped in from one-third to one-fourth less time than at present. Obviously the stopping distance was primarily influenced by two considerations:—(1) The length of the interval which elapsed between the brake being put into operation and its taking an effective grip on the wheels; and (2) the amount of pressure brought to bear on each wheel, and the constancy or otherwise of the action after the blocks had gripped the wheels. The unpleasant sensation often experienced during quick stoppages was produced by intermittent and fitful action. After the brakes had been made to bite the wheels their hold became relaxed, a slip took place, followed by successive bites and slips, the latter giving rise to sudden accelerations of speed. The action of a perfect brake should exactly resemble that which gravity would cause if an ascending incline of uniform gradient could be suddenly placed in front of the train to prevent its motion. Under such conditions no inconvenience or danger need be apprehended from the stoppage being accomplished within even a shorter distance than any that was effected during the experiments. A valuable addition of power, under the immediate control of the driver, would be afforded by the fitting of brakes to the engine, and he was glad to find that the recommendation of the Royal Commissioners in this respect had met with prompt attention at the hands of the railway companies. The question of the best material for brake blocks had of late received a good deal of consideration, and it would seem that cast-iron, and even steel, was fast superseding wood. It generally happened that wheels did not become skidded until the speed of the train had been materially reduced. It seemed desirable, therefore, that for ordinary stops the brake pressure should be applied so as to act just short of skidding the wheels, the full skidding power being only used in cases of imminent danger. The general adoption of an effective system of continuous brakes on carriages which had to run from one line to another would be productive of much advantage, for then, in breaking-up and remaking a train at any junction station, the carriages would be found ready-fitted with the requisite appliances for working. If allied companies could only agree to adopt the same system, brake improvements would proceed with far greater rapidity than at present, and public convenience would thereby be promoted. The time had arrived not only when each system should be scrutinised and tested in the most complete manner, but when the companies should clearly set before themselves the conditions which a good continuous brake ought to supply. A study of the different methods which came under his (the lecturer's) notice during the experiments pointed to the following considerations as necessary in view of the provision of perfect brake power for heavy fast trains:—1. The brake power should be applied to all the wheels of all the vehicles throughout the train. 2. The power by which the blocks were forced upon the wheels should be adequate for skidding the wheels on the speed becoming moderately reduced. 3. The driver should have the whole of the brake power completely under his command, and be able to apply it at a moment's notice, as he was the first person likely to discover any obstruction ahead, and was primarily responsible for the regard of the danger signals. He could thus stop the train at once, and no time would be lost by his having to signal danger to the guard. 4. The guards should individually possess the like means of applying the continuous brake, so that they might be able to stop the train without reference to the driver, on an emergency which might manifest itself to them but not to him, such, for instance, as a broken axle, or a carriage getting off the line. 5. The power in hand should be so susceptible of modification that the driver should be able to apply a moderate amount only for effecting ordinary stops, while he kept in reserve a proper excess to be used only on emergencies, or on slippery rails. 6. Full brake application should not require more than a very moderate effort on the part of either driver or guard. 7. The pressure should be steady, and distributed as equally as possible over all the wheels, and, with the intervention of some elastic medium, should act upon the wheels in such a way as to prevent too sudden stopping or the snapping of chains, which produced discomfort and inconvenience to the public. 8. The machinery should be of simple construction, not likely soon to get out of order, and admitting of being easily repaired. 9. Indication should be constantly afforded to driver and guards that the brakes were in proper condition to work or otherwise. 10. The power of working the tender brakes and the van brakes by hand might be advantageously retained. 11. The brakes should be self-acting in case of the severance of the train. 12. Automatic action being provided, means should be furnished the brake attendants for modifying that action instantaneously, according to the circumstances in which the train might be placed after an accident. 13. It would be dangerous, and therefore unadvisable, to give to passengers any power over the brakes. Such seemed to be the principal conditions necessary for realising the conception of a perfect brake—a brake which would constitute an invaluable instrument in contingencies of almost daily occurrence at some place or another in the great railway network of the country.

REMARKABLE PLANTS

III.—The Sensitive Plant (*Mimosa pudica*).

In our ordinary popular conception of the difference between the two kingdoms into which the organic world is divided, we are apt to attribute to one a power of spontaneous motion dependent on the possession of a certain internal mental faculty to which we apply the term voluntary power; while a similar property is not considered to be inherent in the members of the other kingdom. The most recent researches throw, to say the least, considerable doubts on the universal applicability of this test to distinguish animals from plants. Now that the Desmidieæ and the Oscillatorieæ are, by universal consent, relegated to the vegetable kingdom, and that many bodies described by Ehrenberg as animals are found to be particular stages in the life-history of certain vegetable organisms, this character seems but to follow in the wake of others which have one by one been abandoned as absolute discriminating tests between the members of the two kingdoms. Among the more commonly-occurring and familiar movements of vegetable tissues, the dependence of which on external mechanical causes is at present but imperfectly understood, are those motions of the leaves and other parts of plants which are comprised under the common designation of Movements of Sensitiveness or Irritability. It has been well shown by Sachs[1] that these movements are of three different kinds, viz.:—

1. Those periodic movements which are produced entirely by internal causes, without the co-operation of any considerable external impulse of any kind. Such movements may be termed *automatic* or *spontaneous*,

[1] "Text-Book of Botany," English edition, Book III., chap. 5.

and are illustrated by the rhythmical movements of the small lateral leaflets of the trifoliolate leaf of the Indian "telegraph-plant," *Desmodium gyrans*.

2. Those apparently spontaneous motions of leaves and petals which are due to *alternations in the intensity of light and heat*, and therefore obviously to external causes. It is motions of this kind which give rise to the varying diurnal and nocturnal position of the leaves of some plants, and to the closing of certain flowers in the evening or in wet weather.

3. Those movements of foliage-leaves, or in certain cases of organs belonging to the flower, which are due to *sensitiveness to touch or concussion*. A familiar example of this class of movements is furnished by the well-known irritability of the leaves of the Sensitive Plant; and it is to this class that we propose to confine our attention in the present paper.

Two preliminary remarks may be made, which are applicable not only to the special class of movements now under discussion, but also to the two others to which we have alluded above. All these three kinds of movements are manifested only when the parts in question are perfectly mature, and when the peculiarity of their internal structure, which renders the phenomenon possible, is fully developed. In this respect they afford a remarkable contrast to another class of movements exhibited only when the part of the plant is in active growth, of which we have illustrations in the singular phenomena of climbing stems and tendrils described in detail by Darwin in his "Movements and Habits of Climbing Plants." Another peculiarity common to all the three kinds of movements, and again distinguishing them from the movements of climbing plants, is that they belong entirely to the foliar or appendicular organs, *i.e.*, leaves in the wide botanical sense, as including foliage-leaves, sepals, petals, stamens, and carpels, and not in any case to axial structures or stems and branches.

Sensitive Plant (*Mimosa pudica*, D.C.).

With regard to the anatomical structure of the parts which exhibit the phenomena in question, it is seen that in almost all cases a mass of very succulent parenchyma (small-celled cellular tissue), several layers of cells in thickness, envelopes an axial or central fibro-vascular bundle, or a few such bundles running parallel to one another, these bundles not being sufficiently lignified to be hard, and therefore remaining flexible and extensible, and permitting the upward and downward flexions in which alone the movement generally consists; the whole is enveloped by an only feebly developed epidermis. The best known illustrations of these movements are furnished by the two species of "Sensitive Plant," *Mimosa pudica* and *sensitiva*, but are also exhibited by the leaves of several other *Mimosas*, and of species of *Oxalis*, *Robinia*, *Desmanthus*, and *Smithia*; by the stamens of several species of *Berberis* and of many Compositæ, and by the stigmas of *Mimulus*, *Martynia*, *Goldfussia*, *Stylidium*, and *Megaclinium*. The following account of the mechanical forces which set in motion the phenomena in question is taken mainly from the very laborious researches of Pfeffer.[1]

The very succulent parenchyma is, when the plant is in active growth, always in a very turgid condition; *i.e.*, the cells are absorbing sap freely through their permeable cell-walls by endosmotic force; and in so doing tend to stretch the axial bundle, as well as the epidermis which presents an opposing resistance. The sensitiveness or irritability resides entirely in the parenchyma, either on one or both sides of the fibro-vascular bundle. The irritability depends on a two-fold cause: firstly, the parenchymatous cells are perpetually absorbing water by endosmose, and thus placing the cell-walls in a state of tension; and secondly, a slight impulse imparted to the sensitive cells causes a portion of the absorbed fluid to be driven out through their cell-walls. The cause of the movement itself is believed by Pfeffer to be this: that at the moment when the turgid cells are giving off water, the elasticity of their tense cell-walls comes into play, causing them to contract in proportion to the amount of water expelled. Inasmuch as this water escapes into the intercellular spaces of the sensitive tissue, and from thence is partially transferred to other non-sensitive portions of the plant, the sensitive tissue decreases in volume, while the non-sensitive portion in some other part of the organ becomes correspondingly expanded, the epidermis of the sensitive portion at the same time contracting from its elasticity. This side therefore becomes concave, the other convex; and the sensitive organ in consequence bends, carrying with it whatever other organs it may bear, which therefore rise or fall according as the concavity of the curvature is on the upper or under side of the organ. Immediately after this has taken place the organ is no longer sensitive, the flaccid cells having too little turgidity to allow of the escape of any more water. But after a short time they again absorb water; their turgidity increases; their cell-walls become again stretched or tense; and the previous sensitive condition, as well as the original position of the parts, is again restored.

The following is Sachs' and Pfeffer's description of the anatomy of one of the common Sensitive Plants, *Mimosa pudica*. The leaf is bi-pinnate, consisting of a petiole from 4 to 6 centimetres long, with two pairs of secondary petioles 4 to 5 cm. in length, and on each of these from fifteen to twenty pairs of leaflets 5 to 10 millimetres long and 1·5 to 2 mm. broad. All these parts are connected with one another by the contractile organs described above; every leaflet is immediately attached to the rachis by such an organ from 0·4 to 0·6 mm. long, and this

[1] Pfeffer, Physiologische Untersuchungen, Leipzig, 1873.

again to the primary petiole by another similar organ from 2 to 3 mm. long and about 1 mm. thick. The base of the petiole itself is transformed into a nearly cylindrical contractile organ or "pulvinus," 4 to 5 mm. long and 2 to 2·5 mm. thick, furnished, like those of the secondary petioles, with a number of long stiff hairs on the under side, the upper side being only slightly hairy or entirely glabrous. The pulvinus consists of a succulent parenchymatous tissue of the kind already described. The cells of the under side are thin-walled, those of the upper side have walls about three times as thick. Each cell contains a moderate quantity of protoplasm, a nucleus, small grains of chlorophyll, starch, and, in addition, a large globular drop consisting of a concentrated solution of tannin surrounded by a pellicle.

A somewhat slight concussion of the whole plant causes the contractile organs of the primary petioles of all the leaves to curve downwards, those of the secondary petioles forwards, those of the leaflets forwards and upwards, closing like the wings of a butterfly at rest. After irritation the pulvinus is flaccid, and more flexible than before. A light touch on the hairs on the under side of the pulvinus of the primary and secondary petioles is sufficient to produce the movement; in those of the leaflets the lightest touch on the glabrous upper side. When the temperature is high and the air very damp, the irritability is much greater, and any local irritation incites movements in the neighbouring organs, often in all the leaves of a plant, a phenomenon which has been termed "conduction of irritation." If one of the uppermost leaflets is cut off by a pair of scissors, or its pulvinus touched, or if it is placed in the focus of a burning-glass, the irritation immediately takes place, and this irritation is communicated to the next lower pair of leaflets, and in succession to those at a greater distance; after a short time the leaflets of an adjoining secondary petiole begin to fold together from below upwards, and the same with the other secondary petioles; finally, and often after a considerable time, the primary petiole bends downwards; the phenomenon is then conducted to the primary petiole of the next leaf below, as well as to the next one above. It sometimes happens, however, that particular parts appear to be less susceptible, and do not display the phenomena in question until after they have been once passed by. If the plant is left to itself, the leaflets again expand, and the petioles reassume their erect position after a few minutes; the contractile organs are then again irritable.

That the phenomena of irritability are connected with a displacement of water from the succulent tissue and its replacement by air, is shown by the evident and immediate change in colour; the expulsion of the air from the intercellular spaces and its replacement by water causes the whole organ to assume a darker colour. If, moreover, one of the large contractile organs is cut or punctured, a drop of water immediately escapes from it, and if placed in water it again absorbs it eagerly. A variety of experiments by Sachs, Pfeffer, and Brücke also appear to prove conclusively that the sensitiveness resides in the under, and not in the upper side of the organ.

With regard to external conditions which interfere with the sensitiveness of the leaves of *Mimosa*, they become rigid or insensitive from cold when, the conditions being otherwise favourable, the temperature of the surrounding air remains for some hours below 15° C. (59° F.); the lower the temperature falls below this point, the more quickly does the rigidity set in. With regard to the upper limit, the leaves of the sensitive plant become rigid within an hour in damp air of 40° C. (104° F.), within half an hour in air of 45° C. (113° F.), in a few minutes in air of 49° or 50° C. (122° F.). In water the rigidity from cold sets in at a higher temperature, viz., in a quarter of an hour between 16° and 17° C. (62° F.), and the rigidity from heat at a lower temperature than in air, viz., in a quarter of an hour, between 36° and 40° C. A plant immersed in water of from 19° to 21°·5 C. remains sensitive for eighteen hours or more. The maximum degree of sensitiveness appears to be reached at 30° C. (86° C.), at which temperature the plant is so sensitive that the movement is communicated to a number of leaflets almost simultaneously. During the rigidity from heat, whether in air or water, the leaflets are closed, as after irritation, but the petiole is erect, and when irritated, turns downwards.

If placed in the dark, the irritability to touch is not at first affected, but disappears completely if the darkness lasts for a day or more; when again exposed to light, the sensitiveness is restored after some hours. The position of the parts is, however, very different from that in the insensitive condition caused by heat; the leaflets remain quite expanded, but the secondary petioles are directed downwards, and the primary petiole nearly horizontal. The same effects are caused, though in a less degree, when the supply of light is defective. M. Paul Bert states that the irritability of the leaves of *Mimosa* is destroyed by placing the plant under a bell-glass of green glass almost as completely as if placed in the dark; the plants were entirely killed in twelve days under blackened, in sixteen days under green glass; plants placed beneath white, red, yellow, violet, and blue glasses were still perfectly healthy and sensitive, though varying in the rapidity of their growth.

Drought also causes temporary rigidity. If a plant is left unwatered for a considerable time, the sensitiveness of the leaves perceptibly diminishes with the increasing dryness, and an almost complete rigidity ensues, the primary petiole assuming a horizontal position, and the leaflets expanding; watering the soil causes a return of the sensitiveness after two or three hours.

The same effect is produced if respiration is prevented by exhausting the air. If a plant of *Mimosa* is placed under the receiver of an air-pump and the air gradually exhausted, the leaves first of all fold up, no doubt in consequence of the concussion; but the leaflets then expand, the petiole becomes erect, and, while the leaves assume the same position as after prolonged withdrawal of light, they now remain rigid, resuming their sensitiveness when again brought into the air.

Finally, with regard to the effect of poisonous substances, J. B. Schnetzler has pointed out that the substances which destroy the contractility of animal sarcode also destroy the irritability of the leaves of *Mimosa* and other sensitive organs of plants. Curare has no prejudicial effect in either case, while nicotine, alcohol, and mineral acids destroy both. The vapour of chloroform causes transitory rigidity either in the expanded or in the folded position resulting from irritation.

The genus *Mimosa* is a very large one, forming, together with *Acacia*, the greater part of the sub-order Mimoseæ of Leguminosæ, and embracing about 200 species, natives mostly of tropical America, extending also south of the tropics, and into tropical Africa and the East Indies. They have definite stamens (not more than twice the number of petals), anthers not tipped by a gland, and a pod, the valves of which, when ripe, are either detached entire or break into transverse joints. They are mostly herbs, under-shrubs, or climbers; a few erect much-branched shrubs; one or two trees; a large number are spiny. It is only some of the species that are sensitive. *M. sensitiva*, which is also grown in our greenhouses, differs from *M. pudica* in the leaves having only two pairs of pinnæ, and each pinna only two pairs of ovate leaflets, the inner leaflet of the lower pair being always very small. *M. albida*, another sensitive species occasionally seen in hothouses, has elegant flower-heads of a pale pink colour. Our illustration of *M. pudica* is taken, by permission of Messrs. Longmans, from Thomé's "Textbook of Botany," English edition. A. W. B.